

TABLE 8 ANOVA Comparing Total Vehicle Yielding and Nonyielding During Auxiliary Pedestrian Light On and Off Conditions for South Bayshore Drive at Darwin

Source	SS	df	F	P
Between groups	113.79	3	0.430	0.7335 ^a
Within groups	1,762.83	20		
Total	1,876.62	23		

^aP-value > .05. This result indicates that there is insufficient evidence to suggest a difference in the mean yielding and nonyielding frequency under the auxiliary pedestrian light on or off conditions.

was difficult to see the effect of the pad lighting in the presence of the stutter flash.

SUMMARY AND RECOMMENDATIONS

The stutter-flash device was effective in increasing yielding and reducing conflicts at two crosswalks on two busy multilane roads. It is interesting that the effects were larger for local residents than for staged pedestrian crossings. The addition of departure pad lighting did not appear to have an effect on the percentage of drivers yielding at night. If these effects are replicated in other areas and the effects are maintained over time, this treatment may be a valuable addition to the engineering toolbox. Future research should examine whether

adding flashers on the median island on multilane crosswalks produces higher yielding and whether the effect persists over time.

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REFERENCES

1. Turner, S. M., K. Fitzpatrick, M. A. Brewer, and E. S. Park. Motorist Yielding to Pedestrians at Unsignalized Intersections: Findings from a National Study on Improving Pedestrian Safety. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1982, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 1–12.
2. Van Winkle, J. W., and D. A. Neal. Pedestrian-Actuated Crosswalk Flashers. Presented at ITE 2000 Annual Meeting, Institute of Transportation Engineers, Nashville, Tenn., Aug. 2002.
3. *An Evaluation of a Crosswalk Warning System Utilizing In-Pavement Flashing Lights*. Whitlock & Weinburger Transportation, Inc., Santa Rosa, Calif., April 10, 1998.
4. Huang, H., R. Hughes, C. Zegeer, and M. Nitzburg. *An Evaluation of the LightGuard™ Pedestrian Crosswalk Warning System*. Highway Safety Research Center, University of North Carolina, Chapel Hill, June 1999.
5. Van Houten, R., and J. E. L. Malenfant. ITS Animated LED Signals Alert Drivers to Pedestrian Threats. *ITE Journal*, Vol. 71, 2000, pp. 42–47.

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Walking Speed of Older Pedestrians Who Use Canes or Walkers for Mobility

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Findings are presented of a follow-up study conducted in Winnipeg, Canada, to investigate the walking speed of older pedestrians who use walkers or canes for mobility. The results are from research conducted to understand the differences between the normal and the crossing walking speeds of older pedestrians who use walkers or canes for mobility at signalized intersections. This walking speed is also compared with that of older pedestrians who ambulate without assistive devices. For the purposes of this research, normal walking speed is the speed at which pedestrians walk without needing to cross any intersection, and crossing walking speed is that at which pedestrians walk when crossing a signalized intersection. The research found that in all cases the normal speed is lower than the crossing walking speed for older pedestrians with or without assistive devices. There are no seasonal differences in the normal walking speed of older pedestrians with walkers or canes. However, the crossing walking speed is higher in winter than in summer. Regarding gender issues, older men walk faster than older women when assistive devices are not used. However, there are no gender differences in walking speed when pedestrians use walkers or canes for mobility. Although this research shows that using the current walking-speed assumption of 1.2 m/s (4.0 ft/s), as recommended in the U.S. *Manual on Uniform Traffic Control Devices*, almost all older pedestrians needing walkers or canes for mobility would be excluded in the design process, it also shows other information that would be valuable for improved urban planning, transit operations, and other transportation engineering applications.

Findings are presented of a follow-up study conducted in Winnipeg, Canada, to investigate the walking speed of older pedestrians who use walkers or canes for mobility. The initial research by Montufar et al. (1) showed results regarding the normal and the crossing walking speeds of older and younger pedestrians at signalized intersections. The normal walking speed was defined as the speed at which pedestrians walk when they go about their daily activities without needing to cross a given intersection and without having any external pressures as a result of having to cross the intersection, and the crossing walking speed was defined as the speed at which pedestrians cross the given signalized intersection. This research is a follow-up regarding the walking speed of older pedestrians with mobility impairments and compares these walking speeds with those of older pedestrians who do not need to use assistive devices for mobility.

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Pedestrian walking speed is widely used as input for many transportation engineering applications, such as determining required gap sizes and pedestrian signal timing. The U.S. *Manual on Uniform Traffic Control Devices* (MUTCD) (2) assumes a pedestrian walking speed of 4 ft/s (1.2 m/s) or slower by pedestrians such as the elderly, people using wheelchairs or other assistive devices, and others. The *Manual of Uniform Traffic Control Devices* for Canada (3) refers to ITE publications to assist in the selection of pedestrian walking speeds for signal timing purposes. Therefore, a pedestrian walking speed of 1.2 m/s (4 ft/s) is also common practice in Canada. In addition, the *ITE Traffic Control Devices Handbook* (4) recommends studies to establish the actual 15th percentile pedestrian walking speed or alternatively use of an assumed pedestrian walking speed of 3.5 ft/s (1.07 m/s) in the presence of slower pedestrians.

In January 2006, the National Committee on Uniform Traffic Control Devices approved the proposal presented by the Pedestrian Task Force of the National Committee on Traffic Control Devices to reduce the pedestrian walking speed assumption in the U.S. MUTCD to 3.0 ft/s (0.91 m/s) for the walk phase and clearance interval. Although any modifications to the U.S. MUTCD must be approved by FHWA, if approved, the revised assumption would have significant implications in design and traffic operations. Any reduction to the assumed walking speed in the MUTCD would greatly benefit older pedestrians and pedestrians using assistive devices for mobility.

It is well known that the population is aging rapidly in both Canada and the United States. According to Statistics Canada, in 2006 people aged 65 and older accounted for 13% of Canada's total population (5). Of these, 40% had some disability, with mobility problems being the most common type of disability (6). Statistics Canada also estimates that almost 30% of Canada's population will be 60 years of age and older by 2030, using a medium-growth scenario (7). The U.S. Census Bureau estimates that the population aged 65 and older will grow by over 50% between 2000 and 2020 (8). This rapid change in demographics must be properly accommodated into the transportation system in an equitable and safe manner.

Although extensive research has been done over the years regarding pedestrian walking speed, few studies have addressed real-life environments and pedestrians with mobility impairments.

This research investigates the walking speed of older pedestrians using walkers or canes for mobility in a real-life environment, looking at normal and crossing walking speeds and comparing these with those of older pedestrians who ambulate without assistive devices. The specific objectives of this research were as follows:

- To measure normal and crossing walking speeds of older pedestrians using walkers or canes for mobility at signalized intersections,
- To analyze differences between their normal and crossing walking speeds, and

• To compare the walking speed of older pedestrians who use walkers or canes for mobility with that of older pedestrians who ambulate without assistive devices, as found by Montufar et al. (1).

The research was conducted over a period of 20 months during winter and summer. The data were collected throughout the city as people went about their normal daily activities. The pedestrians in the study were not aware that they were being observed.

PREVIOUS RESEARCH

Pedestrian walking speed is a topic extensively studied over the years. The U.S. MUTCD (2) assumes a pedestrian walking speed of 1.2 m/s (4.0 ft/s) and slower at locations with a high volume of people walking slower than 1.2 m/s as well as pedestrians who use wheelchairs. The *Traffic Control Devices Handbook* (4) recommends studies to establish the actual 15th percentile pedestrian walking speed or alternatively use of an assumed pedestrian walking speed of 3.5 ft/s (1.07 m/s) in the presence of slower pedestrians.

The *Traffic Engineering Handbook* (9) presented research by Perry (10) in which walking speeds were found for physically impaired pedestrians. Study cases included cane or crutch use, walker use, wheelchair use, and pedestrians with an immobilized knee, below-knee amputation, above-knee amputation, hip arthritis, and rheumatoid arthritis (knee). None of the walking speeds in these study cases reached the MUTCD assumed average walking speed of 4 ft/s (1.2 m/s). The average pedestrian walking speed was 2.62 ft/s (0.80 m/s) for people with canes or crutches and 2.07 ft/s (0.63 m/s) for people with walkers.

Two Australian studies investigated pedestrian walking speed at midblock signalized crossings and at signalized intersections. Akçelik & Associates Pty Ltd. (11) studied pedestrian movement characteristics at four midblock signalized crossings of four-lane undivided roads in Melbourne, Australia. Bennett et al. (12) studied four intersections of four-lane roads at busy urban areas in Glen Waverly, Balwyn, Camberwell, and Melbourne City, in Australia. In both studies, data were collected in two surveys of 3- to 4-h periods (one on a week-day and one on the weekend). In addition, pedestrians with walking difficulty were defined irrespective of their age, including the elderly, people with physical impairments, and parents pushing a stroller or paying attention to a young child walking alongside. At midblock crossings, these pedestrians accounted for 8% of the total sample. Their average walking speed was 1.29 m/s (4.23 ft/s) and their 15th percentile walking speed was 1.00 m/s (3.28 ft/s). At signalized intersections, they accounted for 6% of the total sample, and their average walking speed was 1.35 m/s (4.43 ft/s) and their 15th percentile walking speed was 1.15 m/s (3.77 ft/s). However, in both studies, details about the actual total sample size as well as clear definitions of elderly or physically impaired pedestrians were not provided.

Fitzpatrick et al. (13) collected data from 42 study sites in seven states in the United States to determine pedestrian walking speed with consideration of different pedestrian crossing treatments. Pedestrians were classified in six groups according to their age. Two age groups of interest are (a) older pedestrians (those 60 years of age and older but not classified as elderly) and (b) elderly, physically disabled, or both. A total sample size of 2,552 pedestrians was obtained. Of these, 92 were classified as older pedestrians (60 years of age and older), and 15 were classified as elderly, physically disabled, or both. For older pedestrians, the median walking speed was 1.34 m/s (4.38 ft/s), and the 15th percentile walking speed was 0.97 m/s

(3.19 ft/s). For the elderly or physically disabled pedestrians, the median and the 15th percentile walking speeds were 1.03 m/s (3.38 ft/s) and 0.84 m/s (2.75 ft/s), respectively.

TCRP Report 112/NCHRP Report 562 (14) identified and analyzed selected treatments at unsignalized crossings intended to accommodate pedestrians and attempted to determine their effectiveness. The report recommended a walking speed of 3.5 ft/s (1.1 m/s) for the general population and 3.0 ft/s (0.9 m/s) for the older or less able population.

METHODOLOGY

This research involved (a) determining the characteristics of the study groups, (b) selecting the sites for field investigations, (c) determining the sample size, (d) preparing for the data collection, and (e) collecting the data.

Characteristics of Study Group

Walking-speed data were collected for older pedestrians who use walkers or canes at various locations throughout the city of Winnipeg, Canada. Older pedestrians are defined as people appearing to be 65 years of age and older. To avoid any biases in the walking-speed analysis it was decided to exclude the following pedestrians from the data collection process:

- Those walking with children,
- Those walking with dogs or other pets,
- People using assistive devices other than canes or walkers,
- People for whom gender or age were not easily determined by the researchers conducting the data collection,
- Those not completing the distance of interest (i.e., stopping), and
- Those accompanied by someone else and who seemed to be distracted by carrying on a conversation.

Sites for Field Investigations

Eight signalized intersections were selected for data collection to measure the normal and crossing walking speed of pedestrians, as indicated by Montufar et al. (1). These locations had average weekday daily traffic volumes ranging from 8,000 to 49,000 and pedestrian activity ranging from about 1,000 to 15,000 pedestrians per day. None of these intersections have countdown pedestrian signals, and if pushbuttons are in place, no "Walk" signal will appear if the pedestrian does not push the button. Signal timing plans at these locations are conservative and based on the current Canadian MUTCD standards. With the exception of one intersection, all have signal timing plans that assume a walking speed of 1.2 m/s (4 ft/s). The one other location is programmed assuming a walking speed of 1.0 m/s (3.28 ft/s).

In addition to the eight signalized intersections, this research selected one road segment in the south area of the city to measure only the normal walking speed of older pedestrians with walkers or canes. Figure 1 shows the study locations.

Sites were selected on the basis of two primary criteria: demographic characteristics based on the most recent census data and expert knowledge about the demand for pedestrian travel in a given area.

The census information was used to identify areas with high densities of older population. Once these areas were identified throughout

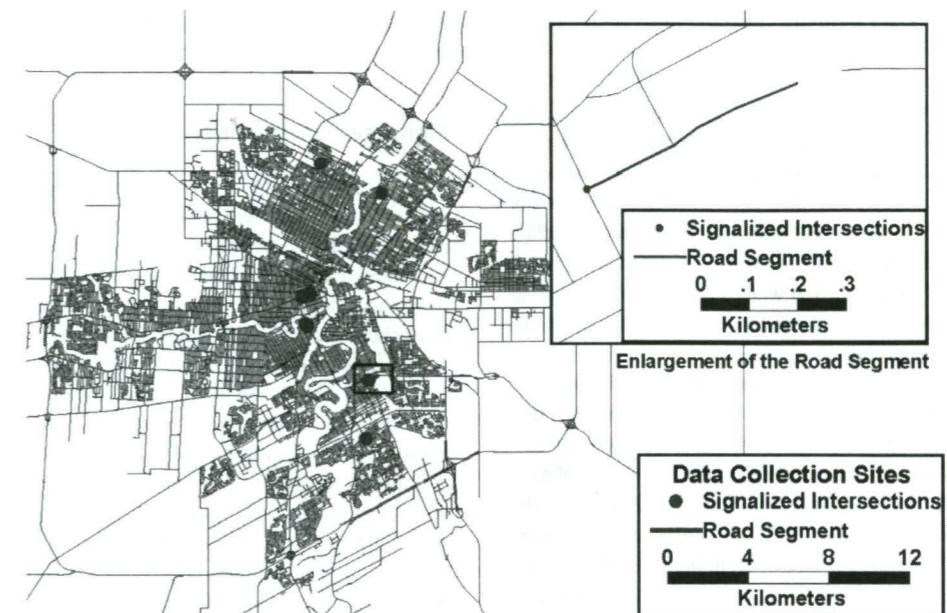


FIGURE 1 Data collection sites.

the city, expert knowledge was used to select sites for data collection purposes.

Sample Size

A minimum sample size of 63 older pedestrians who use walkers or canes was determined to be adequate to analyze statistical differences between normal and crossing walking speed at the 95% confidence level. Similarly, a minimum sample size of 63 older pedestrians who use walkers or canes was required to determine normal walking speed along the selected road segment at the 95% confidence level.

Preparation for Data Collection

At signalized intersections, two types of distances were measured before data collection, as shown in Figure 2 and discussed by Montufar et al. (1). The first distance ($D1$), called the normal distance, is located on the sidewalks a distance away from the intersection; it is used to determine the normal walking speed of pedestrians. Because pedestrians could approach the intersection from different

directions, a total of eight distances $D1$ were identified per location (two per leg, one on either side of each leg). These distances varied from 4 m (13.12 ft) to 12 m (39.37 ft) in length, depending on the location. The second distance ($D2$) corresponds to the crosswalk, measured from curb to curb; it is used to determine the pedestrian crossing speed.

On the road segment, only normal distance ($D1$) was required, as shown in Figure 2. Various normal distances were measured along the segment. These distances varied from 5 m (16.39 ft) to 14 m (45.90 ft) in length, depending on the location. Pedestrians walking on this road segment did not have to cross any signalized intersection.

Data Collection Process

At signalized intersections, data were collected during December, January, and February (months that have snow or ice on the ground) and during May and June (months that show dry road surface conditions). For the purposes of this research, these periods will be referred to as winter and summer.

Along the road, segment data were collected only during June and July. This segment is located near a building that houses a large

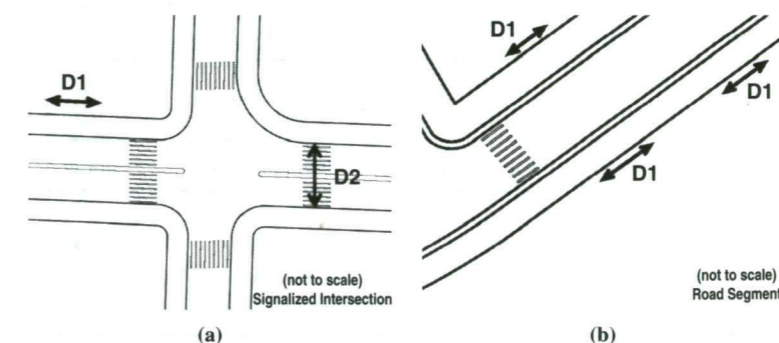


FIGURE 2 Intersection and road-segment layout with distances of interest.

number of older people. Data were not collected in winter because when the sidewalk is covered with snow or ice, these residents tend not to use it and to walk in the road instead.

At each location, unaware pedestrians were timed as they traversed the distances of interest (both normal and crosswalk speeds at signalized intersections and normal speed along the road segment). The times were taken by two data collectors in the field with stopwatches. In the case of signalized intersections, each pedestrian was timed for both the normal and the crosswalk distances (*D1* and *D2*) to determine and compare normal walking speed with crossing walking speed. Along the road segment, pedestrians were timed as they traversed one of the normal distances.

At signalized intersections, pedestrians were timed from the instant they stepped onto the crosswalk to the instant they left the crosswalk (i.e., from curb to curb). Data were collected only for pedestrians starting to cross at the beginning of the "Walk" phase. This data collection was done in 3-h periods in the morning or early afternoon between 10:00 a.m. and 2:00 p.m. at the same location until the minimum required sample size of eight per intersection was achieved. Once that sample was obtained, researchers proceeded to the next intersection.

Along the road segment, researchers collected data in 3-h periods in the morning and in the afternoon from 9:00 a.m. to 12:00 noon and 1:00 to 4:00 p.m.

ANALYSIS AND DISCUSSION OF RESULTS

Seventy-two older pedestrians with walkers or canes were timed at signalized intersections throughout the city to determine their normal and crossing walking speeds. In addition, a total of 118 older pedestrians with walkers or canes were timed along the road segment to determine their normal walking speed only, since they were not crossing any intersections.

A repeated-measures analysis of variance (ANOVA) was conducted to determine whether statistical differences existed between normal and crossing walking speeds for the 72 pedestrians timed at the signalized intersections. Table 1 shows the results of the repeated-measures analysis.

From Table 1 it can be seen that the differences between normal and crossing walking speeds are statistically significant at the 95% confidence level in the case of pedestrians with walkers or canes at signalized intersections ($p < 0.001$). A similar analysis is not needed

for pedestrians operating along the road segment since only normal walking speed was measured in that case.

Signalized Intersections

A two-way ANOVA was conducted to determine if differences in gender and season were statistically significant for each normal and crossing walking speed at the 95% confidence level. Walking speed was treated as the dependent variable, whereas gender and season were the independent variables. The Holm-Sidak test was used to find where the statistical differences were.

The total sample of 72 older pedestrians was used in this analysis. Table 2 shows the average and 15th percentile walking speeds for older pedestrians who use walkers and canes under normal and crossing walking conditions.

Table 2 illustrates that on the basis of average walking speed, older pedestrians using walkers and canes walk faster when crossing the street (0.95 m/s, or 3.12 ft/s) than when walking normally (0.78 m/s, or 2.56 ft/s). These values are statistically different at the 95% confidence level ($p < 0.001$). However, there is no difference between the walking speeds of male and female pedestrians who use these assistive devices. This finding is true at the 95% confidence level ($p = 0.811$ for normal walking speed, and $p = 0.941$ for crossing walking speed).

Regarding seasonal effects on walking speed of older pedestrians with walkers and canes, no statistical differences were found between the average normal walking speed in summer and that in winter ($p = 0.775$). However, the average crossing walking speed appears to be greater in winter (1.01 m/s, or 3.31 ft/s) than in summer (0.87 m/s, or 2.85 ft/s). The result is statistically significant at the 95% confidence level ($p = .007$).

Table 2 also shows the 15th-percentile walking speeds. The same observations are drawn regarding each of the issues previously discussed.

In Figure 3 the cumulative distributions of normal and crossing walking speed of older pedestrians with walkers or canes at signalized intersections are shown. From Figure 3, it can be seen that more than 95% of this population does not reach the design value of 1.2 m/s (4.0 ft/s), as recommended in the current Canadian and U.S. MUTCDs, when they walk normally. Moreover, if the crossing walking speed were used instead, nearly 90% of these pedestrians would be excluded when the MUTCD values are used for design. In addition, the assumed pedestrian walking speed of 3.5 ft/s (1.07 m/s) recommended in the *Traffic Control Devices Handbook* (4) excludes about

TABLE 2 Walking Speed of Older Pedestrians Who Use Walkers or Canes

Description	Number of Records	Percent of Total	Average Walking Speed (m/s)		15th Percentile Walking Speed (m/s)	
			Normal	Crossing	Normal	Crossing
All pedestrians	72	100	0.78	0.95	0.57	0.73
Female	41	57	0.78	0.94	0.57	0.75
Male	31	43	0.77	0.95	0.58	0.73
Summer	33	46	0.78	0.87	0.57	0.66
Winter	39	54	0.77	1.01	0.58	0.81

NOTE: 1 ft/s = 0.305 m/s.

90% and 75% of older pedestrians who use walkers or canes when their normal and crossing walking speeds, respectively, are considered. With the proposed amendment to the U.S. MUTCD to lower the walking speed to 3.0 ft/s (0.91 m/s), nearly 82% and 55% of this pedestrian group would still be excluded from the design on the basis of their normal and crossing walking speeds, respectively.

Along-the-Road Segment

A one-way ANOVA was conducted to determine if differences in gender were statistically significant at the 95% confidence level for normal walking speed along the road segment. Walking speed was treated as the dependent variable, and gender was the independent variable.

The total sample of 118 pedestrians was used in this analysis. Only comparisons regarding gender were possible because the data were collected only during summer.

Table 3 shows that there is no statistical difference between the normal walking speed of female and that of male pedestrians at the 95% confidence level ($p = .863$). The same observations are drawn regarding the 15th-percentile normal walking speed of these pedestrians.

Figure 4, the cumulative distribution of normal walking speed of older pedestrians with walkers or canes along the selected road segment, shows that by using a value of 1.2 m/s (4.0 ft/s), as recommended in the current Canadian and U.S. MUTCDs for traffic signal purposes, nearly all these users are excluded from the design. In addition, the assumed pedestrian walking speed of 3.5 ft/s (1.07 m/s) recommended by the *Traffic Control Devices Handbook* (4) excludes

about 90% of older pedestrians using walkers or canes when one looks at their normal walking speed. Considering the proposed amendment to the U.S. MUTCD to lower the walking speed, about 85% of this pedestrian group would be excluded from the design on the basis of their normal walking speed.

Signalized Intersections Versus Road Segment

Collection of data along the road segment allowed the researchers to increase the total sample size for normal walking speed, which in turn strengthened the quality of the results for this aspect of the analysis.

A one-way ANOVA was conducted to determine if there were differences between the normal walking speed of older pedestrians who use walkers or canes when data were collected at the two different locations (signalized intersections and the road segment). Differences in sample size were addressed in the statistical analysis.

The analysis yielded no statistical differences between the normal walking speed attained at signalized intersections and that for the road segment. This finding was valid at the 95% confidence level ($p = .408$).

Regarding pedestrian gender, no statistical difference in the normal walking speed of women and men was found, with a 95% confidence level.

In a comparison of Figures 3 and 4, it can be seen that slightly slower pedestrians were found along the road segment than at the signalized intersections. However, in general, the same conclusions can be drawn from both graphs regarding the 15th percentile and 85th percentile values.

TABLE 1 Repeated-Measures ANOVA for Walking-Speed Comparisons

Treatment Name	Number of Records	Mean (m/s)	Standard Deviation	Standard Error of the Mean	Confidence Interval of the Mean
Normal walking speed	72	0.78	0.196	0.0231	0.05
Crossing walking speed	72	0.95	0.223	0.0262	0.05
Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	P
Between subjects	71	5.181	0.0730		
Between treatments	1	1.022	1.022	68.096	< .001
Residual	71	1.065	0.0150		
Total	143	7.269			

NOTES: P-value $\leq .05$ indicates that the difference is statistically significant. Power = 1.00 (power of performed test with $\alpha = 0.05$).

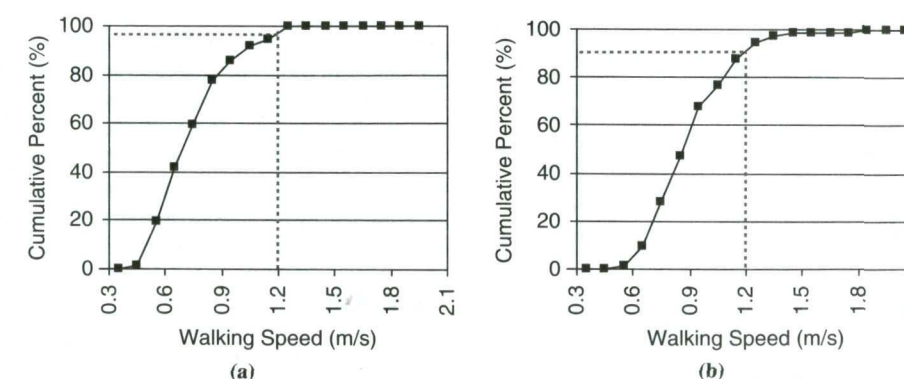


FIGURE 3 Walking speeds of older pedestrians who use walkers or canes for mobility at signalized intersections: (a) normal speed and (b) crossing speed (1 ft/s = 0.305 m/s).

TABLE 3 Normal Walking Speed of Older Pedestrians Who Use Walkers or Canes

Group	Number of Records	Percent of Total	Average Walking Speed (m/s)	Confidence Interval of the Mean	15th Percentile (m/s)
All records	118	100	0.75	0.032	0.56
Only female	68	58	0.75	0.042	0.58
Only male	50	42	0.76	0.049	0.54

NOTE: 1 ft/s = 0.305 m/s.

Comparison with Pedestrians Who Do Not Use Walkers or Canes for Mobility

As previously stated, this research was a follow-up to a research project by Montufar et al. (1) on the normal and crossing walking speeds of younger pedestrians (those who appeared to be between 20 and 64 years of age) and older pedestrians (those who appeared to be 65 years of age and older) at signalized intersections. The following are key comparisons regarding walking speed of older pedestrians with walkers or canes for mobility relative to older pedestrians with no assistive device for mobility. These comparisons are drawn from the current research and that presented by Montufar et al. (1).

Crossing Walking Speed Versus Normal Walking Speed

The crossing walking speed was higher than the normal walking speed for both pedestrian groups at signalized intersections. This finding reflects a behavior in which, regardless of season, age, gender, or ambulatory capability (whether with assistive devices or not), pedestrians walk faster when crossing the street. However, not all pedestrians increase their speed by the same amount from normal to crossing. This speed increment seems to depend on gender and season. In general, there is a 19% increase in average walking speed (from normal to crossing) for older pedestrians who do not use assistive devices for mobility. Comparatively, this change in average walking speed is 22% for older pedestrians with walkers or canes when they are crossing the street; the speed increases from 0.78 m/s (2.56 ft/s) as the normal walking speed to 0.95 m/s (3.12 ft/s) as the crossing walking speed.

The increase in average walking speed is higher in winter than in summer, and it is also higher for older pedestrians with walkers or canes than for older pedestrians not using assistive devices for mobility. In winter, there is a 26% increase in going from the average normal walking speed to crossing walking speed for older pedestrians

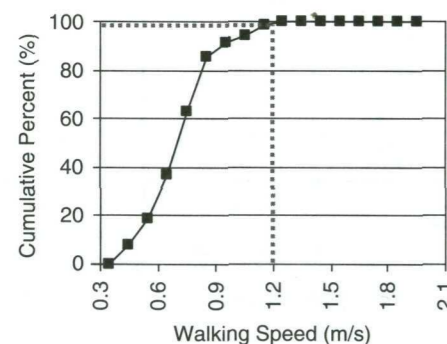


FIGURE 4 Normal walking speed of older pedestrians who use walkers or canes (1 ft/s = 0.305 m/s).

without assistive devices [1.08 m/s to 1.36 m/s (3.54 ft/s to 4.46 ft/s)]. Comparatively, this change in speed is 31% for older pedestrians using walkers or canes [0.77 m/s to 1.01 m/s (2.53 ft/s to 3.31 ft/s)]. This finding means that older pedestrians with canes or walkers have to increase their walking speed by much more than do other older pedestrians when they cross a signalized intersection. This increase is also higher for older women than for older men who do not use assistive devices to cross a signalized intersection. The average walking speed increment from normal to crossing in older pedestrians with walkers or canes is the same for women and men. The increase in average walking speed (from normal to crossing) for older women and men not needing assistive devices is 20% and 18%, respectively. In the case of older pedestrians with walkers and canes, this increment is about 22% for both genders.

Pedestrians with No Assistive Devices

For both normal and crossing walking speeds of older pedestrians with no assistive devices, older men walk faster than do older women. This is not the case for older pedestrians with walkers or canes, where both genders appear to walk at the same speed. This behavior holds true for both the average and 15th percentile walking speeds.

Seasonal Comparison

The normal average walking speed is greater in summer than in winter for older pedestrians with no assistive devices [1.18 m/s (3.87 ft/s) in summer compared with 1.08 m/s (3.54 ft/s) in winter]. However, there is no seasonal difference in normal walking speed for older pedestrians with walkers or canes [0.78 m/s (2.56 ft/s) in summer compared with 0.77 m/s (2.53 ft/s) in winter]. These values are within the range of average walking speed with canes or walkers found by Perry (10) and referenced in the *Traffic Engineering Handbook* (9).

The crossing average walking speed is about the same in winter and summer for older pedestrians with no assistive devices [1.36 m/s (4.46 ft/s) in winter compared with 1.35 m/s (4.43 ft/s) in summer]. However, there is a noticeable seasonal effect for older pedestrians with walkers or canes [1.01 m/s (3.31 ft/s) in winter compared with 0.87 m/s (2.85 ft/s) in summer]. The reason for these differences is not clear, but they could be associated with a desire by pedestrians to minimize their exposure to risk as they cross an intersection.

SUMMARY

Results are presented of research conducted in Winnipeg, Canada, to investigate the walking speed of older pedestrians who use walkers or canes for mobility. The results were compared with findings of previous research by Montufar (1) dealing with walking speed of younger and older pedestrian at the same signalized intersections. A

total of 72 records were collected over a period of 18 months at eight signalized intersections throughout the city to understand the difference between normal and crossing walking speeds of pedestrians, with season and gender taken into account. In addition, 118 records were collected over a period of 2 months on a selected road segment to determine normal walking speed of older pedestrians who use walkers or canes in a real environment. The following key findings were obtained regarding the walking speed of older pedestrians who need walkers or canes for mobility. The conclusions relating to normal walking speed distinguish between signalized intersections and the road segment, since data were collected at both locations for this analysis. However, the conclusions relating to crossing walking speed only relate to signalized intersections.

Normal Walking Speed

The following findings were obtained:

- The average walking speed of older pedestrians using walkers or canes for mobility is 0.78 m/s (2.56 ft/s) at signalized intersections and 0.75 m/s (2.46 ft/s) on the road segment.
- The 15th percentile walking speed is 0.57 m/s (1.87 ft/s) at signalized intersections and on the road segment.
- The average walking speed as well as the 15th percentile walking speed are the same during summer and winter.
- There is no gender difference in average walking speed or 15th percentile walking speed.
- All results are statistically significant at the 95% confidence level.
- Using a design value of 1.2 m/s (4.0 ft/s), as recommended in the current Canadian and U.S. MUTCDs, more than 95% of older pedestrians using walkers or canes would be excluded in the design process on the basis of their normal walking speed. With the proposed amendment to the U.S. MUTCD to lower the walking speed to 3.0 ft/s or 0.91 m/s, this value decreases to approximately 85%.

Crossing Walking Speed

The following are key findings:

- The average walking speed of older pedestrians using walkers or canes for mobility is 0.95 m/s (3.11 ft/s).
- The 15th percentile walking speed is 0.73 m/s (2.39 ft/s).
- Walking speed is greater in winter [1.01 m/s (3.31 ft/s)] than in summer [0.87 m/s (2.85 ft/s)]. This difference is also the case for the 15th percentile walking speed, which is 0.81 m/s (2.66 ft/s) in winter and 0.66 m/s (2.16 ft/s) in summer.
- There is no difference in average walking speed by gender.
- All results are statistically significant at the 95% confidence level.
- Using a design value of 1.2 m/s (4.0 ft/s), as recommended in the current Canadian and U.S. MUTCDs, nearly 90% of older pedestrians using walkers or canes would be excluded in the design process on the basis of their crossing walking speed. With the proposed amendment to the U.S. MUTCD to lower the walking speed to 3.0 ft/s (0.91 m/s), this value decreases to approximately 55%.

CONCLUSIONS

Walking speed is a key input for various transportation engineering applications. Use of an assumed walking speed of 1.2 m/s (4.0 ft/s) when designing for pedestrians is the norm in Canada and the United

States. However, it is well known that as people age they walk more slowly. In addition, as people age, mobility constraints become more frequent, resulting in impairments. When engineers and planners fail in their purpose to properly design for all users, impairments are translated into disabilities.

The provision of an equitable transportation system for all road users is, to a certain extent, dependent on new information about its users. This research presented new information regarding the walking speed of older pedestrians who need walkers or canes for mobility. This information could be used for improved urban planning, transit operations, signal timing, and other transportation engineering applications. Improving the transportation system on the basis of this new knowledge could result in better quality of life for this segment of the population.

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REFERENCES

1. Montufar, J., J. Arango, M. Porter, and S. Nakagawa. Pedestrian's Normal Walking Speed and Speed When Crossing the Street. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2002, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 90–97.
2. *Manual on Uniform Traffic Control Devices for Streets and Highways*. CD-ROM. FHWA, U.S. Department of Transportation, 2003, pp. 4E-1 to 4E-9.
3. *Manual of Uniform Traffic Control Devices for Canada*, 4th ed. Transportation Association of Canada, 1998, Section B4.1.1.
4. *Traffic Control Devices Handbook* (J. L. Pline, ed.). Institute of Transportation Engineers, 2001, pp. 321–326.
5. Statistics Canada. *Population by Sex and Age*. <http://www40.statcan.ca/101/cst01/demo10a.htm>. Accessed July 26, 2007.
6. Housing, Family and Social Statistics Division, Statistics Canada. *A Profile of Disability in Canada*, 2001. Ottawa, Dec. 2002.
7. Statistics Canada. *Projected Population by Age Group According to Three Projection Scenarios for 2006, 2011, 2016, 2021, 2026, and 2031 at July 1st (2026, 2031)*. <http://www40.statcan.ca/101/cst01/demo08c.htm>. Accessed July 26, 2007.
8. *U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin*. U.S. Census Bureau, 2004; Internet release date: March 18, 2004. <http://www.census.gov/ipc/www/usinterimproj>. Accessed July 26, 2007.
9. *Traffic Engineering Handbook*, 5th ed. (J. L. Pline, ed.). Institute of Transportation Engineers, 1999, pp. 36–49.
10. Perry, J. *Gait Analysis: Normal and Pathological Function*. McGraw-Hill, New York, 1992, 490 pp.
11. *An Investigation of Pedestrian Movement Characteristics at Mid-block Signalized Crossings*. Technical Report. Akçelik & Associates Pty Ltd., Australia, Dec. 2001.
12. Bennett, S., A. Felton, and R. Akçelik. Pedestrian Movement Characteristics at Signalized Intersections. Presented at 23rd Conference of Australian Institutes of Transport Research (CAITR 2001), Monash University, Melbourne, Australia, Dec. 10–12, 2001.
13. Fitzpatrick, K., M. A. Brewer, and S. M. Turner. Another Look at Pedestrian Walking Speed. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1982, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 21–29.
14. *TCRP Report 112/NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. Transportation Research Board of the National Academies, Washington, D.C., 2006.

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